

CHAPTER 14

BOILERS

14-1. Types of Boilers

The two most general classifications of heating boilers pertain to the method of manufacture, i.e., by casting (cast iron boilers) or fabrication (steel boilers). Those that are cast usually use iron, bronze, or brass in their construction. Those which are fabricated use steel, copper, or brass, with steel being the most common material.

a. Steel boilers. Steel boilers can be generally divided into two types: fire tube and water tube.

(1) In fire-tube boilers, gases of combustion pass through the inside of the tubes with water surrounding the outside of the tubes. The advantages of a fire-tube boiler are its simple construction and less rigid water treatment requirements. The disadvantages are the excessive weight per pound of steam generated, excessive time required to raise steam pressure because of the relatively large volume of water, and inability to respond quickly to load changes, again due to the large water volume. The most common fire-tube boilers used in facility heating applications are often referred to as scotch or scotch marine boilers, as this boiler type was commonly used for marine service because of its compact size (firebox integral with boiler section).

(2) In the water-tube boiler, the water is inside the tubes and gases of combustion pass around the outside of the tubes. The advantages of a water-tube boiler are a lower unit weight per pound of steam generated, less time required to raise steam pressure, a greater flexibility for responding to load changes, and a greater ability to operate at high rates of steam generation.

b. Cast iron boilers. Cast iron boilers are made in three general types: horizontal sectional, vertical sectional, and one-piece. Most of the sectional boilers are assembled with push nipples or grommet type seals, but some are assembled with external headers and screw nipples. Horizontal, sectional, cast iron boilers are made up of sections stacked one above the other, like pancakes, and assembled with push nipples. Vertical, sectional, cast iron boilers are made up of sections standing vertically, like slices in a loaf of bread. One-piece cast iron boilers are those in which the pressure vessel is made as a single casting.

14-2. Types of systems

Boilers are generally used to provide a source of steam or hot water for facility heating and process needs.

a. Steam and condensate. In steam and condensate systems, heat is added to water in a boiler causing the water to boil and form steam. The steam is piped to points requiring heat, and as the heat is transferred from the steam to the building area or process requiring heat, the steam condenses to form condensate. In some very low-pressure saturated steam heating applications, the steam distribution piping may be sized to slope back to the boiler so that the steam distribution piping also acts as the condensate return piping (single-pipe system). In other low-pressure applications there may be steam supply piping and condensate return piping (two-pipe system) although the condensate system is open to the steam system. In typical packaged steam boiler operations, the boiler system may generate steam at about 150 psig for distribution throughout the facility and be lowered to the operating pressure of equipment

supplied through point-of-use pressure reducing stations. As heat is transferred from the steam, condensate is formed which collects in discharge legs until enough condensate is present to operate a trap that isolates the steam distribution system from the condensate system. In common facility heating applications, the condensate system is at atmospheric pressure and the system is arranged to drain the condensate to a central condensate receiver, or into local smaller receivers which pump the condensate back to the central condensate receiver.

b. Hot water. A boiler is used to heat water that is circulated through a closed loop piping system for general facility and service water heating. Low-temperature systems generally operate below 200°F. Medium-temperature systems generally operate at temperatures between 200 and 250°F. A feature of hot water systems is an expansion tank to accommodate the expansion of the water in the system as the water is heated. The expansion tank, when piped into the system on the suction side of the circulating pumps, also pressurizes the system to prevent flashing in the circulating pump, piping, and piping components. In many low- and medium-pressure systems, pressurization is maintained by flash steam in the expansion tank. In a few hot water systems, pressurization is maintained by maintaining a compressed gas blanket above the water level in the expansion tank.

c. High-Temperature Hot Water. High-temperature hot water systems, which operate above 250°F, are basically the same as hot water systems. High-temperature systems are generally installed when a process requires the higher temperature, a number of locations require small quantities of low-pressure steam that the high-temperature hot water can generate in a local converter, or high-temperature drop equipment can be used at end use points to minimize the size of water circulation piping required.

d. Fuels. Most facility boiler systems are fired using a combustible gas (typically natural gas or propane) or fuel oil. In many facilities, the boilers are designed to fire both a combustible gas fuel and a fuel oil. In these facilities, the combustible gas fuel is generally natural gas that is considered the primary fuel and fuel oil is considered to be the backup fuel. For an expanded discussion of fuel oil properties and fuel oil delivery systems, see chapter 10.

14-3. Boiler system major components

Boiler systems are comprised of the following major components.

a. Feedwater heaters. Feedwater heaters are energy recovery devices generally found only in large steam generating plants where all of the steam generated is not reduced to condensate by the steam user. This "waste steam" is reduced to condensate for return to the boiler in the feedwater heater. The boiler feedwater is used as a cooling medium to reduce the steam to condensate that increases the temperature of the feedwater and thereby increases the thermal efficiency of the boiler.

b. Fuel heaters. Many boilers firing heavy fuel oil require fuel heaters to reduce the fuel viscosity, so the fuel can be atomized by the burner system for complete combustion. For an expanded discussion of fuel oil properties and the function of fuel oil heaters, see chapter 10.

c. Deaerators. A deaerator is a special case of feedwater heater that is designed to promote the removal of non-condensable gases from the boiler feedwater. The principal gases of concern are oxygen, carbon dioxide, and ammonia, which are major contributors to boiler, and steam and condensate piping corrosion problems. In small steam plants, a portion of the steam generated by the boiler is used to operate the deaerator if "waste steam" is not available. Failure to maintain and properly operate the deaerator can lead to early failure of the boiler, steam using equipment, and the steam and condensate

pipings.

d. Pumps. In most hot water systems, the system circulating pumps are electric motor-driven, end suction centrifugal pumps. In steam systems, the condensate return pumps are typically electric motor-driven, end suction, centrifugal or turbine type pumps. Feedwater pumps are generally electric motor-driven, multiple-stage, end suction centrifugal pumps. The shutoff head of the pump must be greater than the steam or hot water system operating pressure.

e. Combustion air blowers. In many packaged boiler installations, the combustion air fan is designed and provided by the boiler manufacturer and is integral with the boiler housing. In installations where a stand-alone fan is provided, low-pressure centrifugal blowers are commonly used. An important characteristic of the blower is the ability to maintain a relatively constant air pressure over a wide range of airflows.

f. Flues. Flues (boiler firebox exhaust duct or boiler discharge stack) must be large enough to conduct the products of combustion away from the boiler with a minimum of duct friction loss. Flues may be fabricated from any material suitable for the operating temperature and pressure. Common materials of construction associated with packaged boiler installations are carbon steel and stainless steel.

14-4. Boiler system controls

The control configuration for a boiler installation depends on the size of the boiler, the requirements of the insurance company providing coverage for the facility, and the building codes of the locality in which the facility is located. The overall boiler control system is typically integrated through a control panel known as the burner management system which controls the boiler operation to maintain the system set point conditions and shuts down the boiler if an equipment damaging and life threatening condition is sensed. For most packaged boiler installations, the basic boiler control is a single-element, proportional control device. In the case of a steam boiler, the control device is a pressure sensing element that sends a signal to the burner management system to adjust the burner firing rate to maintain a set pressure in the steam distribution system. In a hot water boiler, the control device is a temperature sensing element. In large steam boiler installations, the control system may be a three-element, proportional-integral-derivative controller that not only responds to the system set pressure, but may also respond to the rate of change in parameters, such as pressure, steam flow, water level, etc. In multiple boiler installations, the burner management systems of each boiler may be controlled by a master plant controller (sometimes referred to as a lead-lag controller) to stage boiler operation to minimize on/off operation. They may also minimize frequent burner cycling which can cause thermal stresses leading to tube and tube sheet leaks. While a brief description of the common types of control components associated with packaged boilers follows, the best guide to facility boiler operation and boiler controls is the manufacturer's operating and maintenance instructions provided with the boilers.

a. Common controls. The following control devices are common to all boilers.

- (1) The forced draft fan motor drives forced draft fan directly to provide combustion air.
- (2) The forced draft fan motor starter energizes forced draft fan motor.
- (3) The forced draft fan furnishes all air, under pressure, for combustion of pilot fuel and main fuel, and for purging prior to burner ignition and after burner operation termination.

- (4) The ignition transformer provides high-voltage spark for ignition of gas pilot or light oil pilot.
- (5) The modulating motor operates the rotary air damper and fuel valves through a cam and linkage system to provide proper air-fuel ratios under all boiler load conditions.
- (6) The low fire switch is an internal auxiliary switch, cam-actuated by the modulating motor shaft, which must be closed to indicate that the air damper and fuel metering valve are in the low fire position before an ignition cycle can occur.
- (7) The burner switch is a manually operated start-stop switch for directly starting and stopping operation of burner.
- (8) The manual-automatic switch, when set at "automatic," subsequently operates at the command of the modulating control which governs the position of the modulating motor in accordance with load demand. When set at "manual," the modulating motor, through the manual flame control, can be positioned at a desired burner firing rate. The primary purpose of the manual position is for testing and setting the air-fuel ratio through the entire firing range.
- (9) The manual flame control is a manually operated potentiometer that permits the positioning of the modulating motor to a desired burner firing rate when the manual-automatic switch is set on manual. It is used primarily for initial or subsequent setting of fuel input throughout the firing range. It has no control over the firing rate when the manual-automatic switch is set on "automatic."
- (10) The modulating motor transformer reduces control circuit voltage to required voltage for operation of modulating motor (typically reduces 115 volt alternating current to 24 volt alternating current).
- (11) Indicating lights provide visual information of flame failure, load demand, fuel valve (valve open), and low water.
- (12) The program relay and flame safeguard control (flame safety system) automatically programs each starting, operating, and shutdown period in conjunction with operating limit and interlock devices. This includes, in a timed and proper sequence, the operation of the blower motor, ignition system, fuel valve(s), and damper motor. The sequence includes air purge periods prior to ignition and upon burner shutdown. The flame detector portion of this control monitors both oil and gas flames and provides protection in the event of loss of a flame signal. The control recycles automatically during normal operation, or following a power interruption. It must be manually reset following a safety shutdown caused by a loss of flame. Incorporated is an internal checking circuit, effective on every start, that will prevent burner operation in the event anything causes the flame relay to hold in during this period.
- (13) The combustion air proving switch is a pressure sensitive switch actuated by air pressure from the forced draft fan. Its contacts close to prove presence of combustion air. The fuel valves cannot be energized, unless this switch is satisfied.
- (14) The combustion air damper controls combustion air in proportion to fuel input for various load demands. It may be of the butterfly, opposed blade, or rotary type.

b. Steam controls (all fuels). The following control devices are used with steam systems.

- (1) The steam pressure gauge indicates boiler internal pressure.
- (2) The operating limit pressure control breaks a circuit to stop burner operation on a rise of boiler pressure above a selected setting. It is adjusted to stop or start the burner at a preselected pressure setting.
- (3) The high limit pressure control breaks a circuit to stop burner operation on a rise of pressure above a selected setting. It is adjusted to stop the burner at a preselected pressure above the operating limit control setting. This control is normally equipped with a manual reset.
- (4) The modulating pressure control senses changing boiler pressures and transmits this information to the modulating motor to change the burner firing rate when the manual-automatic switch is set on automatic.
- (5) The low water cutoff and feedwater pump control (typically float-operated) responds to the water level in the boiler. The control starts and stops the feedwater pump or operates the feedwater control valve to maintain the proper water level in the boiler. If the water level drops below the lowest safe water level for the boiler, the control shuts down the boiler.
- (6) Most jurisdictions required two independent low water cutoff devices. The auxiliary low water cutoff also provides a signal to shut down the boiler if the water level drops below the lowest safe water level for the boiler.
- (7) The water column provides visual indication of boiler water level. The water column and low water cutoff devices for a boiler are typically incorporated in the same piping assembly.
- (8) The test valve allows the boiler to be vented during filling and facilitates routine boiler inspection. The test valve is typically incorporated in the same piping assembly as the water column and the low water cutoff.
- (9) Safety valves relieve the boiler of pressure higher than the design pressure. Safety valves and discharge piping must conform to the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code requirements.

c. *Hot water controls (all fuels).* The following control devices are used with hot water systems.

- (1) The water temperature gauge indicates the internal water temperature.
- (2) The water pressure gauge indicates the pressure in the boiler.
- (3) The operating limit temperature control breaks a circuit to stop burner operation on a rise of boiler temperature above a selected setting. It is adjusted to stop or start the burner at a preselected operating temperature.
- (4) The high limit temperature control breaks a circuit to stop burner operation on a rise of temperature above a selected setting. It is adjusted to stop the burner at a preselected temperature above the operating control setting. The high limit temperature control normally is equipped with a manual reset.

(5) The modulating temperature control senses changing boiler temperature and transmits this information to the modulating motor to change the burner firing rate when the manual-automatic switch is set on automatic.

(6) The low water cutoff breaks the circuit to stop burner operation if the water level in the boiler drops below a safe operating level.

(7) Most jurisdictions require two independent devices to terminate boiler operation in the event of low water. The auxiliary low water cutoff also provides a signal to stop burner operation if the water level in the boiler drops below a safe operating level.

(8) Relief valves relieve the boiler of pressure higher than the design pressure. Relief valves and discharge piping must conform to the ASME Boiler and Pressure Vessel Code requirements.

d. Gas controls. The following control devices are used with gas-fired boilers.

(1) The gas pilot valve is a solenoid valve that opens during the ignition period to admit fuel to the pilot. It closes after main flame is established. The sequence of energizing and de-energizing is controlled by the program relay and flame safeguard control. Some jurisdictions may require two independent gas pilot valves installed in series.

(2) When two independent gas pilot valves are required, a normally open vent valve is usually required to vent the section of gas piping between the valves whenever both gas pilot valves are de-energized. The vent valve closes when the gas pilot valves are energized.

(3) The gas pilot shutoff cock is a manually operated, non-lubricated plug valve for isolating the gas supply from the gas pilot valve.

(4) The gas pilot adjusting cock is a manually operated valve used to regulate the size of the gas pilot flame.

(5) The gas pilot aspirator is a venturi device using combustion air to improve the flow of gas to the pilot burner.

(6) The gas pilot pressure gauge indicates gas pressure in the supply line to the gas pilot.

(7) The gas pilot pressure regulating valve reduces incoming gas pressure to suit the requirements of the pilot burner. Most pilot burners require a gas pressure in the range of 5 to 10 inches of water column.

(8) The main burner gas flow control valve is modulated through a mechanical linkage to the modulating motor to regulate the flow of gas to the burner in proportion to the boiler load.

(9) The gas modulating cam is an assembly consisting of a quadrant, a series of adjustable allen head screws, and a contour spring to adjust gas input at any boiler load condition to attain the required air-fuel ratio. The position of the quadrant is controlled by the modulating motor.

(10) The main gas cock is a manually operated, non-lubricated plug valve for isolating the gas supply from the main gas valves.

(11) Most jurisdictions require two independent main gas valves in series. Main valves will open only after the program relay and flame safeguard control signals that a pilot flame has been established.

(12) The main gas vent valve is a normally open solenoid valve installed between the two main gas valves to vent gas to atmosphere should any be present in the main gas line when the gas valves are de-energized.

(13) The low gas pressure switch is a pressure-actuated switch that is closed whenever the pressure in the gas supply line is above a preselected pressure. If the gas pressure in the gas main drops below the set pressure, the low gas pressure switch opens breaking the circuit to the main gas valves which causes the main gas valves to close, terminating burner operation.

(14) The high gas pressure switch is a pressure-actuated switch that is closed whenever the gas supply line pressure is below a preselected pressure. If the gas pressure in the gas main rises above the set pressure, the high gas pressure switch opens breaking the circuit to the main gas valves which causes the main gas valves to close, terminating burner operation.

e. Oil controls. The following control devices are used with oil-fired (or dual fuel) boilers.

(1) The oil drawer switch is a limit switch which remains open preventing the burner from operating until the oil drawer burner gun is latched in the forward position.

(2) The atomizing air proving switch is a pressure switch that closes allowing the burner to operate when there is sufficient atomizing air pressure for proper burner operation. Oil valve(s) will not operate or will not remain open, unless the atomizing air proving switch remains closed.

(3) The air pump module provides the compressed air required to atomize the fuel oil for proper burner operation. It is started automatically by the program in the program relay and flame safeguard control system.

(4) The air pump motor drives the air pump and an air-cooling fan. The control for the motor operates in parallel with the forced draft fan motor.

(5) The air pump provides air for atomizing the fuel oil.

(6) The air filter, typically, an oil bath or viscous film filter element (see chapter 7 for an expanded discussion of air filter assemblies) is used to clean the air supply prior to entering the air pump.

(7) The check valve prevents lubricating oil and compressed air from surging back through the pump and air filter when the air pump stops.

(8) The air-oil receiver tank holds a supply of oil for lubricating the air pump. It separates lube oil from atomizing air before delivery to the burner nozzle.

(9) The atomizing air pressure gauge indicates the pressure in the atomizing air supply system near the connection to the burner.

- (10) The lube oil level sight glass indicates the level of lubricating oil in the air-oil receiver tank.
- (11) The lube oil cooling coil cools the lubricating oil before the oil enters the air pump. A fan driven by the air pump motor circulates cooling air over the coil.
- (12) The lube oil strainer filters lubricating oil before the oil enters the air pump.
- (13) The lube oil fill pipe and strainer are used when adding oil to the air-oil receiver tank.
- (14) Some jurisdictions require a low oil pressure switch. When required, this pressure-actuated switch opens when the pressure in the fuel oil supply system drops below a set value.
- (15) The oil solenoid valve opens when energized by the program relay and flame safeguard control system allowing fuel oil flow from the oil metering valve to the burner nozzle. Many jurisdictions require two independent oil solenoid valves in series for boiler fired-on light oils.
- (16) The fuel oil controller is an assembly combining into a single unit the gauges, regulators, and valves required for regulating the flow of fuel oil. Most controllers have the following integral parts. In addition to the parts listed below, controllers on systems burning No. 6 or heavier fuel oil required additional parts that are described in paragraph 14-4.f.
- (a) The oil metering valve is operated through a mechanical linkage to the modulating motor. The valve regulates the fuel oil supply to the burner nozzle in proportion to the boiler load.
- (b) The oil modulating cam is an assembly consisting of a quadrant, a series of adjustable allen head screws, and a contour spring to adjust gas input at any boiler load condition to attain the required air-fuel ratio. The position of the quadrant is controlled by the modulating motor.
- (c) The oil burner pressure gauge indicates the pressure in the fuel oil supply line at the inlet connection to the oil metering valve.
- (d) The oil pressure regulator may be required to reduce the pressure in the facility fuel oil delivery system to a pressure compatible with the oil burner fuel oil supply regulating components.
- (17) The oil relief valve bypasses excess fuel oil and maintains the fuel oil system pressure indicated on the oil supply pressure gauge.
- (18) When a light oil pilot system is used, a solenoid valve is provided to control the flow of fuel to the pilot nozzle. The pilot valve is energized at the appropriate time by the program in the program relay and flame safeguard control system. It shuts off the flow of fuel to the pilot when the control system receives a signal that the main burner flame has been established. (Note: Many oil burners use a gas pilot system consisting of the components described in paragraph 14-4d.)
- (19) The back pressure orifice is a restriction located in the oil return line immediately downstream of the fuel oil controller to maintain a set pressure in the fuel supply system. A back pressure orifice is generally only used on systems that do not use an oil relief valve.
- f. *Heavy oil controls.* The following additional control devices are used when firing heavy oil.

- (1) The oil heater switch is a manual disconnect for electric power to fuel oil heater system.
- (2) The oil heater – electric – is used for heating sufficient fuel oil for operating burner at low fire during cold starts before steam or hot water is available for fuel oil heating. On steam boiler units, the electric heater is typically integral with the steam fuel oil heater. On hot water boiler units, the electric heater is typically a stand-alone unit. The electric heater must be turned off during extended boiler lay-up or at any time fuel oil transfer is terminated.
- (3) The oil heater – steam or hot water – heats the fuel oil to attain the proper fuel oil viscosity for full atomization of the fuel oil. On steam boilers operating at 15 psig or less, the steam heater typically operates at the same pressure as the boiler. On higher pressure steam boiler units, a pressure reducing station is typically installed in the supply line to the fuel oil heater to limit the steam pressure in the oil heater to 15 psig or less.
- (4) The oil heater thermostat – electric and steam – senses fuel oil temperature. On electric heaters, energizes or de-energizes the electric heater to maintain the proper fuel oil temperature. On steam heaters, controls the operation of the steam flow control valve in the supply line to the heater to maintain temperature.
- (5) The oil heater thermostat – hot water – senses fuel oil temperature and starts and stops a booster water pump which circulates hot water from the boiler through the oil heater to control the temperature of the fuel oil.
- (6) The booster water pump circulates water from the hot water boiler through a hot water fuel oil heater. Operation of the pump is controlled by the hot water oil heater thermostat.
- (7) The oil heater valve is a normally open solenoid valve opened by the steam boiler heater thermostat to allow flow of steam to the steam heater to maintain the temperature of the fuel oil.
- (8) The steam heater supply check valve is installed in the steam supply line ahead of a steam oil heater, the check valve prevents oil contamination of the waterside of the pressure vessel should any leakage occur in the oil heater.
- (9) The steam heater pressure regulator is used on steam boiler units that operate at pressures higher than 15 psig to reduce the steam pressure supplied to the steam oil heater to pressures compatible with the equipment.
- (10) The steam trap drains condensate and prevents loss of steam from the steam oil heater. The discharge of the steam trap on the steam oil heater unit is typically discharged rather than recovered to eliminate the possibility of contaminating the waterside of the boiler in the event of a leak in the oil heater unit.
- (11) The steam heater discharge check valve prevents air entry during shutdown periods when cooling action may create a vacuum within the steam heater.
- (12) The oil supply pressure gauge is installed in the fuel oil supply line between the discharge of the fuel oil heater and inlet to the fuel oil controller unit oil pressure regulator.
- (13) The low oil temperature switch is a temperature-actuated switch that prevents the burner

from firing or terminates burner operation if the fuel oil temperature is lower than required for proper oil burner operation.

(14) High oil temperature switch. Some jurisdictions require a temperature-actuated switch that prevents the burner from firing or terminates burner operation if the fuel oil temperature is above a set temperature. This is the high oil temperature switch.

(15) The fuel oil controller units for boilers firing heavy oil require the following.

(a) The fuel oil thermometer indicates temperature of fuel oil being supplied to the fuel oil controller.

(b) The back pressure valve ensures that a minimum fuel oil supply system pressure is maintained for proper fuel oil controller operation.

(c) The oil return pressure gauge indicates the oil pressure on the return side of the fuel coil controller.

(d) The manual bypass valve is used when making a cold start. When open, bypasses control elements and allow oil circulation through the supply and return system to allow oil heaters to adjust the temperature of the fuel oil before firing the burner is attempted. The valve must be closed prior to firing the boiler.

(e) The orifice oil control valve may be opened prior to startup to aid in establishing fuel oil flow through the controller. Prior to firing the boiler, the valve must be closed.

(16) The air purge valve is a solenoid valve that opens simultaneously with closing of oil solenoid valve at burner shutdown allowing compressed air to purge oil from the burner nozzle and adjacent piping. This oil is burned by the diminishing flame which continues burning for approximately four seconds after the oil solenoid valve closes.

(17) The air purge orifice nozzle limits purging air to proper quantity for expelling unburned oil at the normal delivery rate.

(18) The air purge orifice nozzle filter filters the purging air of any particles that might plug the air purge orifice nozzle.

(19) The air purge check valve prevents fuel oil from entering the atomizing air line.

(20) The air purge relay, when energized, controls the operation of the air purge valve.

g. *Additional controls for dual-fuel burners.* Boilers with dual-fuel burner systems require a selector switch to tell the control system which set of fuel controls to operate.

h. *Economizer.* An economizer is an energy recovery device that uses the hot exhaust gases from the boiler (waste heat) to heat combustion air or feedwater.

i. *Steam traps.* Steam traps are installed throughout steam systems to remove condensate (spent steam), air, and non-condensable gases from the steam system. There are five types of steam traps in

general use today. While other types have been designed and built, the requirements of industry have centered around the five basic types described below.

(1) The heart of a balanced pressure thermostatic trap is the flexible bellows that moves the valve head from its seat to discharge the condensate. The bellows is filled with a volatile fluid and hermetically sealed. The fluid has a pressure-temperature relationship that closely parallels, but is approximately 10°F below that of steam.

(2) The liquid expansion steam trap has for its operating element a liquid-filled cartridge. Within this cartridge is a hermetically sealed bellows which is attached to the valve head and plunger.

(3) Float and thermostatic steam traps provide immediate and continuous discharge of condensate, air, and non-condensables from a steam system as soon as they reach the trap. The trap consists of a ball float connected by a lever assembly to the main valve head. As condensate reaches the trap, the ball float rises, positioning the valve to discharge the condensate at the same rate as it reaches the trap.

(4) The inverted bucket steam trap is a type of trap with an inverted bucket attached to the valve head by a lever mechanism and operates to open and close the trap. When condensate enters the trap, a water seal is formed around the bottom of the inverted bucket which, since it is filled with air, becomes buoyant and rises and closes the trap. A small hole in the top of the inverted bucket allows air to escape with condensate taking its place inside the bucket. The inverted bucket loses its buoyancy and sinks to the trap bottom, opening the valve to discharge the condensate.

(5) Thermodynamic steam traps are a type of steam trap which responds to differences in kinetic energy between steam and condensate to open and close the valve for discharging condensate.

j. Piping. Piping 2 inches and smaller used in steam and hot water systems is typically schedule 80, American Society for Testing and Materials (ASTM) A 106, Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service (1999), Grade B, steel pipe with threaded joints and carbon steel fittings. Piping larger than 2 inches is typically standard weight, ASTM A 106, Grade B, steel pipe with flanged joints and carbon steel fittings.